575

VOLUME 80 SEPARATE No. 575

PROCEEDINGS

AMERICAN SOCIETY
OF
CIVIL ENGINEERS

DECEMBER, 1954

AMERICAN SOCIETY OF CIVIL ENGINEERS FOUNDED 1852

A GEOMETRIC PROBLEM IN TRAVELING CRANE TRACK ALIGNMENT

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SURVEYING AND MAPPING DIVISION

{Discussion open until April 1, 1955}

Headquarters of the Society
33 W. 39th St.
New York 18, N. Y.

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This paper was published at 1745 S. State Street, Ann Arbor, Mich., by the American Society of Civil Engineers. Editorial and General Offices are at 33 West Thirty-ninth Street, New York 18, N. Y.

A GEOMETRIC PROBLEM IN TRAVELING CRANE TRACK ALIGNMENT

J. E. Oliver[1] and F. A. Maloney[2]

INTRODUCTION

The problem presented herein deals principally with track alignment for those traveling cranes termed "Portal". The term Portal relates to the construction of the cranes which allows automotive and rail traffic to pass beneath the body and between the legs of the crane. (See figure 1). So called "low portal" wide gauge cranes are also used by the Navy.

The fact that the largest of these cranes weigh seven hundred tons, can lift seventy five tons and travel on track gauge up to forty feet, together with the accompanying illustrations will give the reader an idea of the size of these cranes and the magnitude of the problem posed and explained in this article.

Prior to 1900 these Navy yard cranes traveled on tangent track only. In later years the use of curved tracks was introduced. The ability of the cranes to traverse curved tracks obviously gives great flexibility of crane usage throughout the shipyard. It has been estimated that the number of cranes required has been reduced about 50% by the use of curved tracks.

The Navy is one of the few organizations using traveling cranes which uses curved trackage (See figure 2).

The Problem

Curving the tracks introduced gauge reduction as delineated in figure 3. Once the crane is completely on the curve having correctly reduced gauge it will travel with little or no damage to the crane. The problem therefore is to move the crane from the normal gauge tangent to the reduced gauge curve. This was at first accomplished entirely with lateral "float" action built into the travel mechanism. "Float" is the ability of the crane trucks to move laterally in relation one to the other, which in effect changes the gauge of the crane itself. Present day cranes are still constructed with this float action but due to the amount of the gauge reduction required on the short radius wide gauge tracks now used (at one Navy yard, 40' gauge, 12-3/4" reduction) it is impractical to accomplish this with float action alone. The function of the transition curve described herein is to reduce the amount of motion which the float mechanism must provide. However, no transition curve can eliminate the necessity for providing some floating action.

The Solution

It is apparent by geometry (see figure 3) that, due to the non-radial position of the ends of the crane, the gauge of the track must be reduced on curves to accommodate the lateral movement of the travel trucks. For a given radius the reduced gauge, G, is obtained by the formula:

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$$G = \left(R^2 + 2e\sqrt{R^2 - f^2} + e^2\right)^{1/2} - R$$

The derivation of this formula shows that it is simply a compounding of the Pythagoras Theorem. The first step in the derivation, as diagramed in figure 3, is to determine the equivalent length of crane, i.e. the length of a theoretical crane that has its corners riding over the rails when all the wheels of the actual crane are on the rails.

Having obtained the equivalent length of crane and knowing the radius of the curve to be negotiated, the precise reduced gauge (G) can be computed by again applying the Pythagoras Theorem. This procedure is also diagramed in figure 3.

An alternative method for computing the reduced gauge (G) is diagramed in figure 3a. Since the distance f (1/2 the equivalent length of crane) can be readily computed, it may be more convenient to employ trigonometric tables rather than work with squared functions.

Figure 3 and the following explanation shows the method for computing the reduced gauge for a simple curve and scheme for transition from tangent gauge e to reduced gauge G.

While the actual gauge reduction for a given radius can be computed precisely, the gradual reduction between tangent gauge "e" and reduced gauge "G" must necessarily be an approximation. The transition curve for a two rail portal crane should be accomplished by spiralizing the inside rail and for a four rail portal crane by spiralizing the centerline of the inside tracks, computing the reduced gauge (G_1 thru G_{10}) using the radius of each of the ten points of the spiral and setting the outside rail or centerline by offsets from the inside rail or centerline (see figure 3). The length of the spiral should be a minimum of twice the length of crane.

The spiral, which has a beginning radius of infinity and for which spiral tables are readily available, does not diverge rapidly enough in the beginning to allow for switching operations. The following method uses that part of such a spiral between R maximum (300′ to 400′) and R minimum (see figure 4). This is a combining spiral with the R maximum circular curve being used in theory only.

All spiral calculations herein are based on the fundamental functions of the spiral, the X and Y coordinates. The calculations required for setting up tables for X and Y are very involved and laborious.

$$x = L_s\left\{100 - \theta_s^2\left[.0030461 - \theta_s^2\left(\overset{7}{.0}429592 - \overset{12}{.0}301987\,\theta_s^2\right)\right]\right\}^{*}$$

$$y = L_s\theta_s\left[.58177641 - \theta_s^2\left\{\overset{4}{.0}1265852 - \theta_s^2\left(\overset{9}{.0}1226911 - \overset{15}{.0}652559\,\theta_s^2\right)\right\}\right]$$

Tables for these functions may be found in any publication dealing with the cubic spiral. The methods of obtaining all other spiral functions are given herein.

$^{*}\ \overset{7}{.0} = .0000000$

With reference to Figure 4
Given D1, and D2 and the length of the combining spiral La, the total length of spiral (Ls) is computed as follows:
Determine the length L (R of infinity to R maximum sub-spiral)

$$L = \frac{L_a}{D_2 - D_1} \cdot D_1 \qquad L_s = L_a + L$$

The central angle of the combining spiral

$$\theta = \frac{L_a}{200} \cdot D_1 + \frac{L_a}{200} \cdot D_2$$

The central angle of the sub-spiral

$$\theta_1 = \frac{L_a}{200} \cdot D_1$$

The central angle of the total spiral

$$\theta_s = \theta_1 + \theta$$

The central angle to any point on the spiral

$$\theta_n = \frac{L_n^2}{L_s^2} \cdot \theta_s$$

The radius to any point on the spiral

$$R_n = \frac{R_{min} \cdot L_s}{L_n}$$

Xc and Yc - coordinates of the total spiral are found in tables using

θ_s and L_s as arguments.

p and k may be found in tables using θ_s and L_s as arguments or as follows:

$$p = y_c - R_{min} \cdot \operatorname{vers} \theta_s$$

$$k = x_c - R_{min} \cdot \sin \theta_s$$

The spiral tangents T1 and T2 are determined as follows:

$$I \text{ to } I_s = x_c - \left(x - \frac{y}{\tan \theta_1} + \frac{y_c}{\tan \theta_s} \right)$$

$$T_1 = \left(\frac{\overline{II_s}}{\sin \theta} \cdot \sin \theta_s \right) - \frac{y}{\sin \theta_1}$$

$$T_2 = \frac{y_c}{\sin \theta_s} - \left(\frac{\overline{II_s}}{\sin \theta} \cdot \sin \theta_1 \right)$$

The spiral may then be located by the deflection method or by X and Y offsets from the T. S. In the offset method it is necessary to coordinate the

required points with "A" being the point of origin. The relation of the T. S. to any point on the curve is then a matter of plane coordinate relationship.

With reference to Figure 5

The distance from PIa to T.S. (Ts) is determined as follows:

$$T_s = \frac{\left\{(R_{min}+p)(\tan \tfrac{1}{2}\Delta_b)+k-\left(x-\frac{y}{\tan\theta_1}\right)\right\}\cos\tfrac{1}{2}\Delta_b}{\cos\tfrac{1}{2}\Delta_a} - \frac{y}{\sin\theta_1}$$

X and Y are found in tables using θ_1 and L as arguments: see figure 4 for p and k.

The above procedure is applicable to the curve which is transitional throughout, commonly called the double spiral, this spiral combination may be more aptly termed a Double Combining Spiral. For the double combining spiral it is necessary to determine the R (min) as follows:

$$D_{max} = \frac{\Delta_a \cdot 100}{L_a} - D_{min} \quad ; \quad R_{min} = \frac{5729.578}{D_{max}}$$

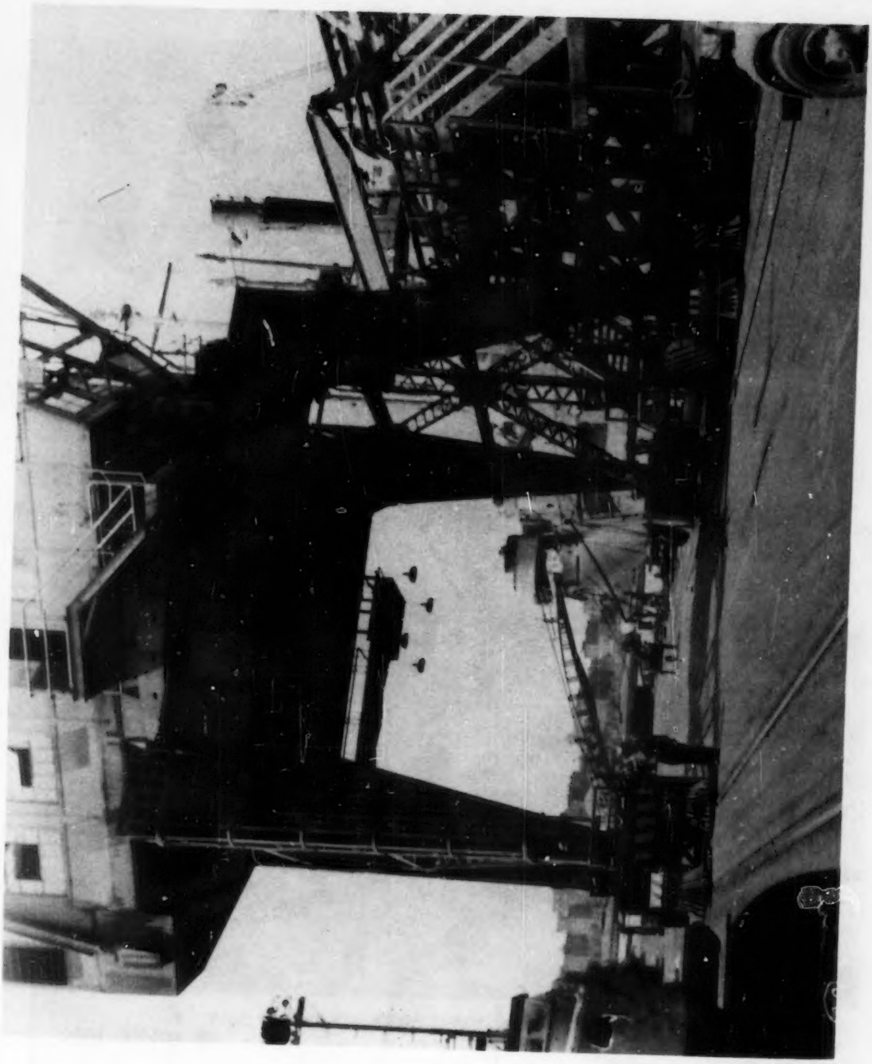
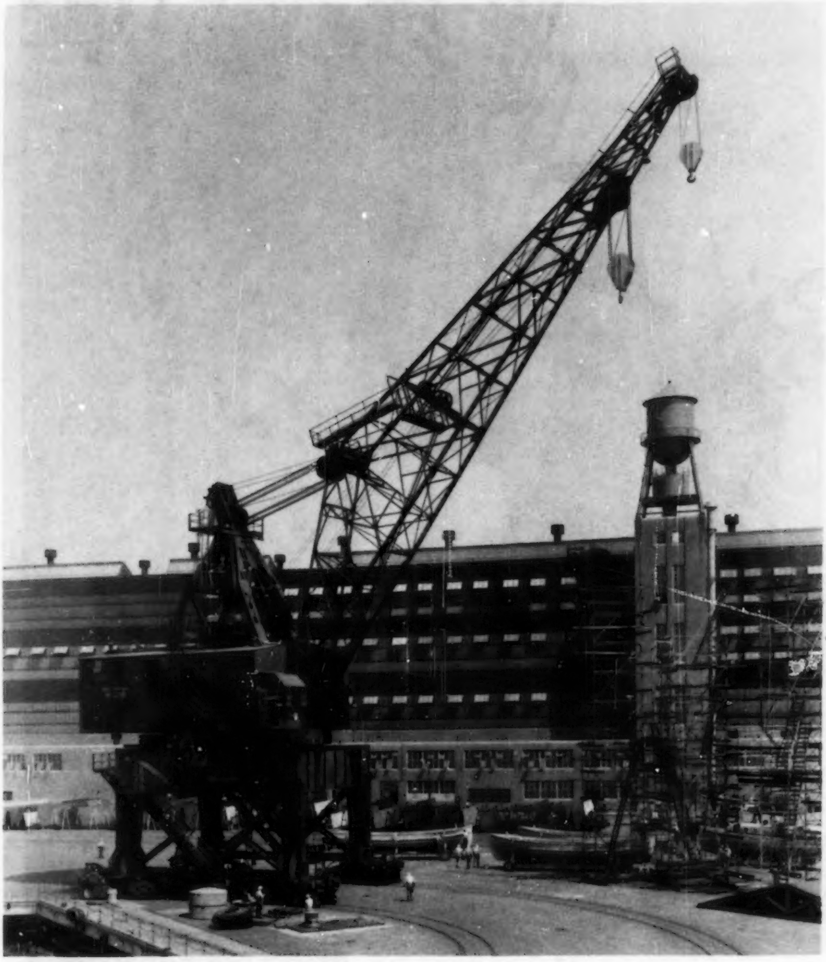


Fig. 1



NEW YORK NAVAL SHIPYARD, NAVAL BASE, BROOKLYN 1, N. Y.
NY3-266(L)-8-50 28 AUGUST 1950
PORTAL CRANE. 75 TONS.

Fig. 2

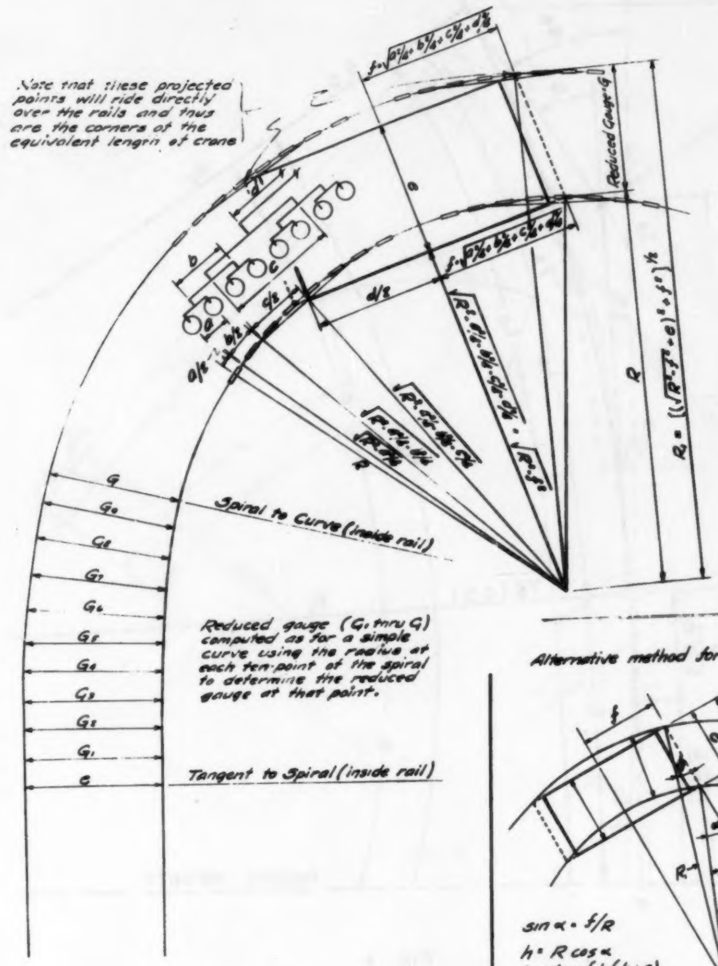


Fig. 3

Alternative method for computing G

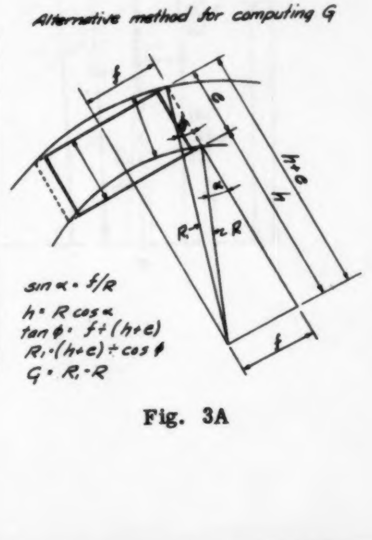


Fig. 3A

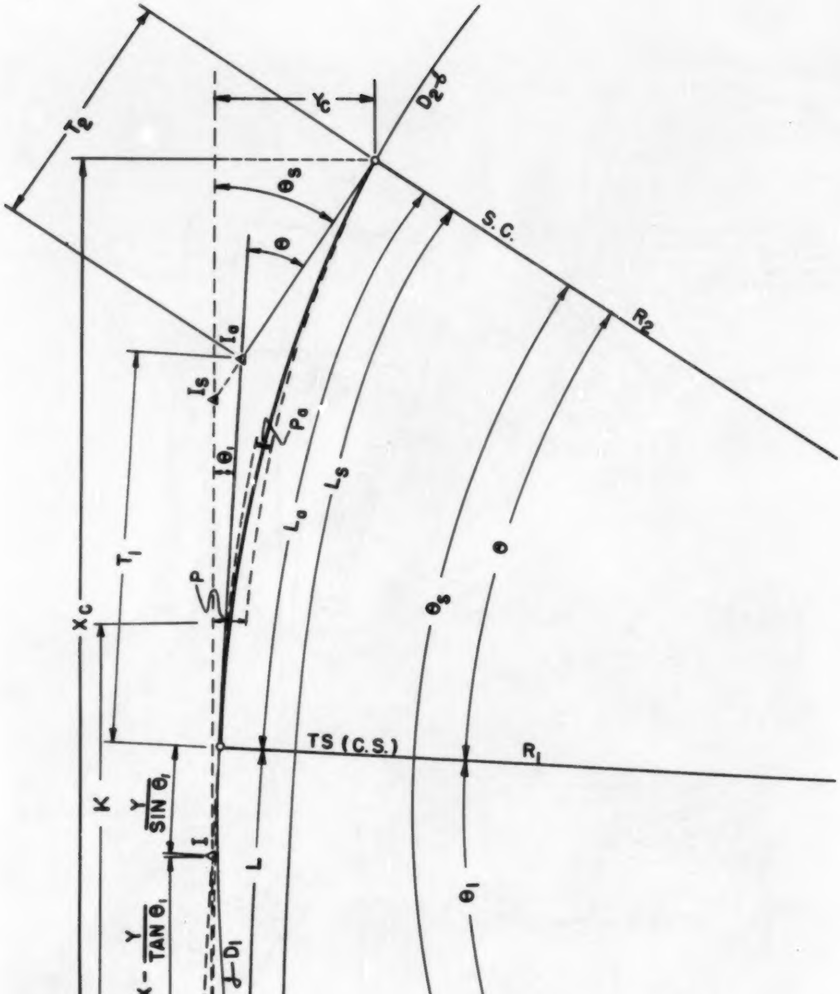

T2
Yc
D2-δ
θs
θ
S.C.
R2
Ia
Is
Pa
θ1
La
Ls
θ
T1
P
Xc
θs
K
TS (C.S.)
R1
Y / SIN θ1
I
L
θ1
X - Y / TAN θ1
D1
A
RADIUS INFINITY

Fig. 4

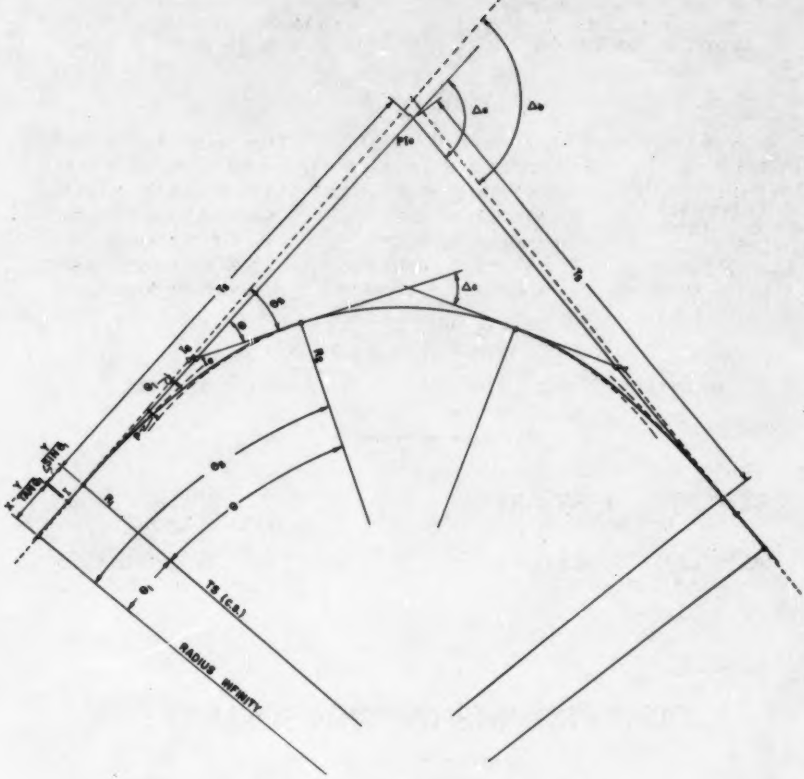


Fig. 5

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